ON THE REARING OF HONEY POSSUMS

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INTRODUCTION

The marsupial Honey Possum (*Tarsipes rostratus*), weighing between 6 and 12 g, is found in the *Banksia* heathlands of the south-west corner of Western Australia. It is exclusively nectarivorous, being totally dependent upon nectar and pollen, derived principally, from species of Proteaceae, Epacridaceae and Myrtaceae (Wooller, *et al.*, 1984)

Although the biology of the Honey Possum has been studied quite extensively, (see Russell and Renfree, 1989), very little is known of its reproductive physiology. Three months has been suggested as the gestation length for this species (Wooller, *et al.*, 1981). As with most kangaroos and wallabies, mating occurs around the time of birth. This ensures that the early embryos, or blastocysts, remain in a state of delayed development, or diapause, (Renfree, 1980) while lactation is supporting the young in the pouch, a process which lasts for about 10 weeks. All the major development of the embryos, or organogenesis, is reported as being short (Renfree, pers. com.) and, presumably, must occur near the last stages of lactation. Unlike diapause in the Macropodidae, however, the act of suckling does not completely suppress the development of the blastocyst (Renfree, 1980;1981). Neither does the termination of suckling stimulate the resumption of the development of the embryos (Renfree *et al*, 1984). It has been suggested, rather, that environmental factors may be associated with the resumption of development and the ensuing phase of organogenesis within the gestation (Russell and Renfree, 1989).

As part of a laboratory study to determine the nitrogen requirements of Honey Possums, a colony was established within the Department of Zoology at the University of Western Australia. We report, here, the conditions that have encouraged the mating of animals in captivity and allowed the females to retain and rear their young. As well, the monitoring of reproductive activity in several females throughout this time has revealed a variation in the length of the gestation period, a feature that may be inherent in the reproductive cycle of this species.

MATERIALS AND METHODS

Three female Honey Possums, identified as #2(August 1996), #16(March 1997) and #128-7(June 1997), were trapped (date in parentheses) in pitfall traps in the Scott National Park (SNP) and, on arrival in Perth, were placed in indoor perspex cages, 160cm x 80cm x 100cm, located in a controlled temperature room (CTR). Day/night cycle (10hr:14hr) was regulated at 24°C and 14°C respectively. The cages were supplied, approximately weekly, with

some fresh Proteaceae blossoms, together with greenery, and were furnished with small wooden nest boxes. The volume of diet (see below) consumed and the weight of each animal was recorded daily and it was during this period that both the concentration of sugar and the daily ration of the diet were optimised. Honey Possums have been recorded as ingesting excessive amounts if fed *ad libitum* (Slaven and Richardson, 1988) and our animals, kept in the indoor cages, soon became obese if the dietary ration was increased or if the sugar content was greater than 22%. No evidence of obesity was observed, however, when the dietary volume was increased during the time the animals were in the outdoor yards.

Two further females, #4 and #11(both collected in November 1996), were placed immediately in an outdoor cage (Yard 1), measuring 4m x 4m x 2m, constructed with $1cm^2$ wire mesh, overlaid with fly-wire mesh in order to prevent the escape of any young. After variable periods of time, the animals housed indoors were transferred outdoors to an identical cage alongside (Yard 2). Both cages were planted with species of *Banksia, Isopogon, Grevillea, Eremophila, Callistemon* and *Adenanthos*. Small saplings (*Corymbia calophylla*) and a ground cover (*Kennedya coccinea*) provided further refuge. Flowering occurred during the time of study, but as the blossoms were sparse, their contribution to the diet was considered to be minimal.

From isotopic turnover studies in the field (Bradshaw & Bradshaw,1996) we have been able to calculate that the Honey Possum exchanges almost its total body weight in water each day. This figure includes 11% metabolic water production and, in some cases, free water, but the majority is nectar. Thus, 10ml of liquid diet was the daily ration to each animal and was presented in 20ml syringes held upright with a spring clip mounted on a perspex stand.

The diet, previously developed by Russell and Renfree (Russell and Renfree, 1989), was modified to provide 54% of the dietary nitrogen in the form of pollen (see Table 1). As the commercial brand obtained from a local health foods store contained very little of the pollen preferred by Honey Possums, it was considered prudent to retain the protein supplements, Sanatogen (Fisons Pty Ltd) and Complan (Glaxo Labs., N.Z. Ltd). The amount of nitrogen in the daily ration was also increased from 5.6mg to approximately 20mg, as this amount is equivalent to that contained in the volume of pollen estimated as the average quantity ingested daily in the field (Bradshaw & Bradshaw, 1996). The concentration of sugar in the diet (measured with a BRIX refractometer) also corresponds to the concentration of sugar measured in the nectars of their preferred food plants in the Scott National Park.

The dietary ration during July to December was increased two-fold for the animals in Yard 2 in an attempt to stimulate these females into a reproductive phase. The animals in Yard 1 were used as a control and were maintained on the single rations. During the five months, however, the loss of animals from Yard 1 remained undetected, and it was most probable that the two remaining females also had access to double rations.

RESULTS

PROGRESS OF MOTHERS

Female #4 (11.3g) was captured 23

Table 1. Honey Possum diet: components of the daily ration

INGREDIENT	VOLUME ml/g	NITROGEN mg	RATION ml/animal/ day	NITROGEN mg/day	NITROGEN % of total	SUGAR %
Water	240					
Honey	400	100		0.46	8.2	
Pollen	4	179		0.82	14.6	
Sanatogen	5	672		3.05	54.6	
Complan	11	278		1.27	22.6	
Russell and Renfree (1989)			3ml	5.6		50
Water	425					
Honey	150	38		0.64	3.4	
Pollen	13.5	603		11.02	54	
Sanatogen	2.6	349		6.38	31.2	
Complan	5.5	142		2.6	12.7	
Our study			10ml	20.6		22

November 1996, and placed on arrival in Yard 1. She was left undisturbed until 27 August 1997, transferred indoors to CTR for 2 weeks, returned to Yard 1 and not captured again until 10 February 1998, weighing (11.7g). Her pouch was inspected for the first time and new-born young were present. She was caught again 4 March, (10.9g), and her pouch young were estimated to be 3 weeks old. When caught on 11 March (13.1g), a single pouch young was confirmed.

Animal #11 (9.5g) was also captured 23 November 1996, and placed on arrival in Yard 1. Similarly, she was left undisturbed until 27 August 1977, when she spent 2 weeks indoors in the CTR (11.2g). On 11 September, she was returned to the outside yard and on 8 February 1998, she was first noticed with pouch young, one of which had emerged from the pouch. She was trapped on 10 February (10.1g), together with her two female young-at-heel, #32-4 (2.8g) and #32-5 (3.1g). Her mammary glands were still enlarged. She was trapped again on 19 February (9.4g), this time alone, and again on 4 March (9.3g) when two small young, approximately 2 weeks old, were present in the pouch. She was next caught on 18 March (12.6g), and her two pouch young with developed tails, were estimated to be 1 month old.

Animal #128-7 (7.6g) was captured on 17 June 1997 (during a mating period) and was maintained in the CTR until 29 August, when she was transferred outdoors. She was left undisturbed until trapped on 15 October and one small pouch young was present. By 20 November, the female young (#32-6) was observed outside the pouch and, on 15 December, was feeding independently and weighed 3.9g. On 4 March 1998, the mother (12.6g), had two small pouch young estimated to be 2 weeks old. When caught again on 18 March, the two pouch young were estimated to be one month old.

Animal #16, (13.1g), was captured on 30 March 1997 and placed in the CTR on 2 April. She was transferred to the outdoor yard on 23 June and left undisturbed until captured on 15

October, when two pouch young were present. By 20 November, both young had emerged from the pouch and were feeding independently from the syringe. On 15 December, the male young (#32-1) weighed 5.3g and the female young (#32-2) weighed 8.1g. The mother was next caught on 19 February 1998 (16.7g) and had two new-born pouch young. She was caught again on 18 March, and the two pouch young were estimated to be 3 weeks old.

Animal #2, (9.4g) was captured on 19 August 1996 and was maintained in the CTR until 23 June 1997. At all times she was housed with males, and under daily observation; there was no evidence of any pouch young during the 10 months that she remained indoors. She was transferred outdoors on 23 June 1997, weighing 15g and had no pouch young. On 20 November, two large pouch young were present and were first seen out of the pouch on 1 December.

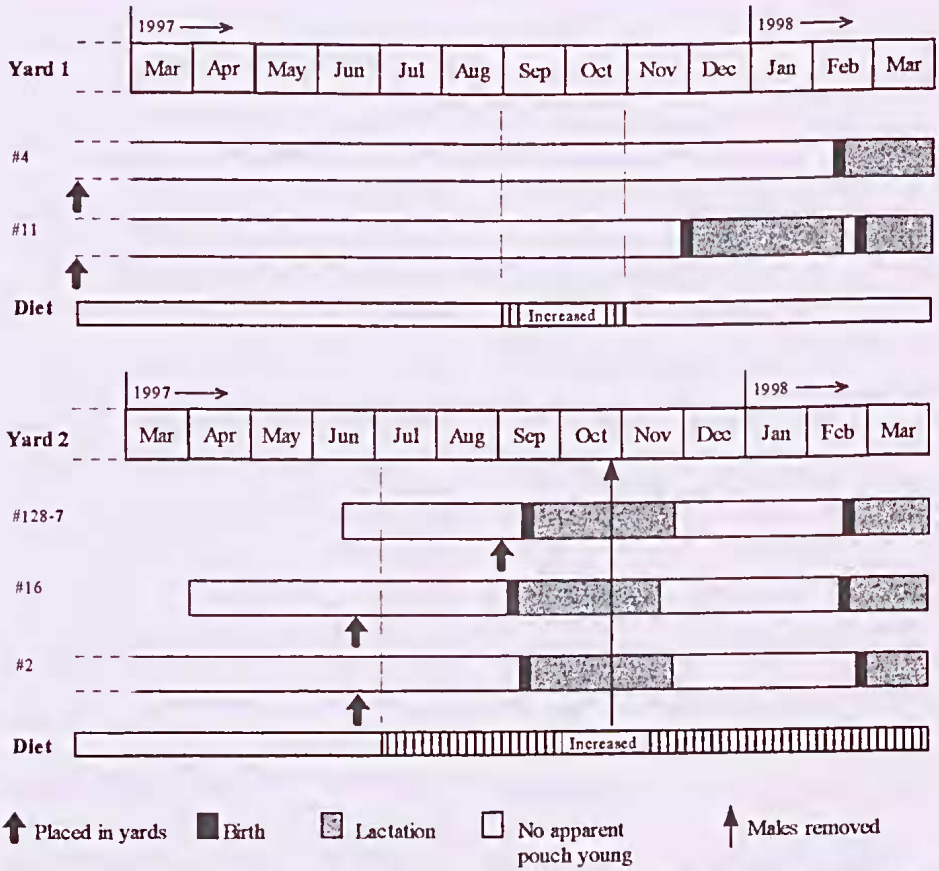

Figure1. Reproductive record of five female Honey Possums in the captive colony. The females in Yard 1 were always in the company of more than one male. In Yard 2, all males were removed on 25 October 1997 in order to protect the lactating females and their young and were not re-introduced until 28 February 1998.

By 5 December, they were foraging independently from the mother. Both young-at-foot were female (#32-7 weighed 3g on 10 December and #32-3 weighed 3.9g on 15 December). The mother was trapped again on 4 March 1998 (14.5g) and had two small pouch young estimated to be 1 week old. She was next caught on 18 March (16.4g) and her two pouch young were estimated to be 3 to 4 weeks old.

PROGRESS OF OFFSPRING

The juvenile Honey Possums were weighed at several intervals during the first one hundred days following pouch emergence and their growth, calculated from the equation of the line (Figure 2), increased at the rate of 2g per month.

Of the seven young produced, six were female, one of which did not survive to adult weight.

DISCUSSION

Female Honey Possums were observed to rear their young successfully in captivity when their maintenance dietary ration was doubled. The successful weaning by the one female kept on single rations

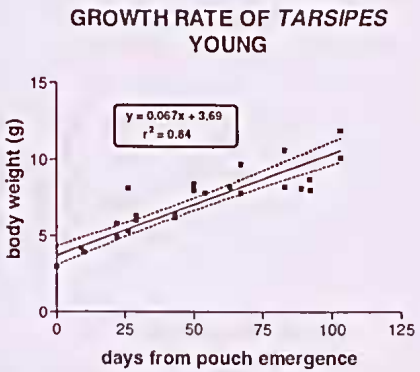

Figure 2. Growth rate of Honey Possum offspring born in captivity.

for a year can best be explained by the lack of competition for the diet, unobserved by us, resulting in an effective increase in her ration.

Although the release of the three females into the outdoor conditions was also concomitant with their reproductive success, this may have been serendipitous. Two females had been maintained in the outdoor yard for a year and, under daily observation, showed no evidence of reproduction. These females may have been inhibited by a lack of plant cover in the first six months of the year. Although we provided 4 wooden nest boxes, they were generally eschewed by the animals which preferred small rock piles or dense ground cover for refuge. Also, the females which bred successfully were observed to defend fiercely their distance from another female, and usually returned to the same location during the day. Whether the conditions in yard 1 were too stressful for females to rear young successfully cannot be concluded here. The advantage provided by the outdoor conditions may have more to do with allowing the animals to exercise, thereby preventing them from becoming obese as a result of the increased dietary ration. The fact that all females gave birth synchronously in mid-February does suggest the action of some environmental cue denied the animals when sequestered in a laboratory environment (Bronson, 1985).

Our rationale for the diet was to provide the components in similar amounts to those we measured in the field. Turner (1984) has previously estimated that the minimum protein requirement of a 15g Honey Possum is 110mg per day which would provide the animal with 17.6mg of nitrogen. She also estimates that an individual would be able to satisfy this

requirement by visiting some 2,000 *Banksia* florets daily, representing approximately 3-4 inflorescences (Turner, 1984). We have been unable to confirm Turner's estimate of minimum nitrogen requirements for the Honey Possum, which comes from the equation of Smuts (1935) relating basal metabolic rate and endogenous nitrogen metabolism in a range of eutherian mammals. We estimate, also using Smuts' equation, that a 10g Honey Possum would require only 4.8mg of nitrogen daily to remain in nitrogen balance and this is close to the figure of 2.8mg N per day ($89mgN.kg^{-0.75}.day^{-1}$) which we have determined experimentally in feeding trials in the laboratory (Bradshaw & Bradshaw, subm.). For an active animal, our field data suggest that the daily intake of nitrogen is closer to 20mg N and, therefore, this amount was used as the basis when formulating our diet. In an effort to stimulate reproduction, the daily intake was further increased to 30 - 40mg N. These amounts are equivalent to 0.75 to 1g pollen, and, again, are quite consistent with our findings in the field where pollen intake may be as high as 2g in some individuals (Bradshaw & Bradshaw, 1999).

The weaning of 5 pouch young towards the end of November strongly suggests that the three females in yard 2 all gave birth during the first half of September (see Figure 1). Three months prior to this, female #128-7 was collected from the field during a period of mating and was probably fertilised in the field. The coincidence of birth in the other 2 females(#16 and #2) that had been in captivity for 2 months and 10 months respectively, suggests a degree of synchrony in either the period of oestrus or the major developmental stage of the gestation (referred to as the 'active' stage by Russell and Renfree, 1989). Although not recorded, the females in yard 1 may have experienced oestrus at the same time, even though there was no evidence of any young produced, as their pouches were not examined during the period. Certainly, female #11 must have mated sometime prior to the birth of her two young in late November.

A remarkable feature of this study is the synchronous birth of young in all females in both yards in mid-February. We have no information during this time for the population in the Scott National Park on the southern coast, but Russell and Renfree (1989) describe a 'synchronised peak of births in late January-February' in the Mount Manypeaks region, which is at a similar latitude to the Scott National Park but some 600km eastward.

Another surprising feature was the apparent difference between the periods of gestation in the two separated groups of animals. Assuming that the three females in yard 2 were fertilised at the time of birth, the period between fertilisation (September, 1997) and birth of the next young (mid-February, 1998) was approximately 5 months, whereas, in the single female in yard 1 that produced two litters, it was barely 3 months (December to February). There may have been enough time for the three females in yard 2 to have experienced a second pregnancy, but the removal of the males in October negates this possibility. The apparent difference between the gestation periods indicates that the obligatory period of diapause during the gestation can be variable in length. In this case, the blastocysts that were conceived in October were held over through the summer period to allow birth in February.

CONCLUSION

Successful reproduction of the marsupial Honey Possum in captivity can be achieved with the provision of semi-natural outdoor conditions and a daily supplementary diet containing a minimum of 30mg nitrogen per day for each animal. This study also shows that the length of the diapause during gestation in Honey Possums is not fixed and may vary from three to five months.

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REFERENCES

BRADSHAW, S. D. & BRADSHAW, F.J. 1996. Reproduction in marsupials: the private life of an obligate nectarivore, the Honey Possum, *Tarsipes rostratus*. *In: Energetics of reproduction in birds, mammals and reptiles: exploring new technologies*. (Eds. R. Drent & P. Jouventin), pp 7-8. Centre National de la Recherche Scientifique, Chize, France.

BRADSHAW, S.D. & BRADSHAW, F.J. 1999. Field energetics and the estimation of dietary intake of pollen and nectar in the marsupial honey possum, *Tarsipes rostratus*, in heathland habitats of south-western Australia. *J. Comp. Physiol. B* 169, 569-580.

BRONSON, F.H. 1985. Mammalian reproduction: an ecological perspective. *Biol. Reprod.*, 32: 1-26.

RENFREE, M. B. 1980. Embryonic diapause in the Honey Possum, *Tarsipes spenserae*. *Search*, 11: 81.

RENFREE, M.B. 1981. Embryonic diapause in marsupials. *J.Reprod. Fert.*, 29: 67-78

RENFREE, M. B., RUSSELL, E. M. & WOOLLER, R. D. 1984. Reproduction and life history of the Honey Possum, *Tarsipes rostratus*. *In: Possums and Gliders*. (Eds. A. P. H. Smith & I.D. Hume), pp 427-437. Surrey Beatty & Sons with Australian Mammalian Society. Sydney.

RUSSELL, E. M. & RENFREE, M. B. 1989. Tarsipedidae. *In: Fauna of Australia*. (Eds. D. W. Walton and B. J. Richardson), pp 769-782. Australian Government Publishing Service. Canberra.

SLAVEN, M. R. & RICHARDSON, K. C. 1988. Aspects of the form and function of the kidney of the Honey Possum, *Tarsipes rostratus*. *Aust. J. Zool.*, 36: 465-471.

SMUTS, D. B. 1935. The relation between the basal metabolism and the endogenous nitrogen metabolism, with particular reference to the estimation of the maintenance requirement of protein. *The Journal of Nutrition*, 9: 403-433.

TURNER, V. 1984. Banksia pollen as a source of protein in the diet of two Australian marsupials *Cercartetus nanus* and *Tarsipes rostratus*. *Oikos*, 43: 53-61.

WOOLLER, R. D., RENFREE, M. B.,

RUSSELL, E. M., DUNNING, A., GREEN, S. W. & DUNCAN, P. 1981. Seasonal changes in a population of the nectar feeding marsupial *Tarsipes spenserae* Marsupialia: Tarsipedidae). *J. Zool., Lond.*, **195**: 267-279.

WOOLLER, R. D., RUSSELL, E. M. & RENFREE, M. B. 1984. Honey Possums and their foodplants. *In: Possums and Gliders.* (Ed. A. P. Smith & I. D. Hume), pp 439-443. Surrey Beatty & Sons. Sydney.